APPLICATION OF CRYSTAL PLASTICITY TO FRACTURE ANALYSIS IN METALLIC MATERIALS

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The constitutive equations currently used for fracture analysis in ductile metals are primarily written on a macroscopic scale, using classical plasticity models such as von Mises plasticity [1]. Accurate simulation of the fracture process zone calls for bypassing classical plasticity models and using plasticity models of fundamentally characteristic length scales at atomistic or grain levels. The feasibility of fracture modeling on the microscale level has been recognized [2]. Here we report our recent work on developing three-dimensional fracture analysis tools using finite element method based on crystal plasticity.

Polycrystalline microstructures are represented by the aggregate of grains, bearing a different lattice orientation in each grain. This can be done using Voronoi tessellation [3], or through digitalization of micrographs when experimental data are available. The constructed geometry model is meshed such that each grain is represented by one or more finite elements. Assuming slip is the predominant plastic deformation mechanism, a rate-independent material model is implemented to describe the constitutive behavior of single crystals, aiming at FCC metals [4]. The primary variables of the model are Cauchy stress, crystal slip systems, deformation gradient, and plastic deformation gradient. The model has the advantage of being suitable for implementation in a displacement-based finite element code.

Some verification results will be reported. Parameter studies, including geometrical variations on the morphology of the microstructure, textures, and size of the mesh, are conducted to identify numerical parameters of major importance. Implications of the developed computational approach based on crystal plasticity to micro-crack initiation and propagation will be discussed.

References

[1] R.H Dodds, Jr., "*WARP3D – 3-D Nonlinear Fracture Analysis of Solids*," Department of Civil Engineering, University of Illinois, 2002.
[2] B. Cotterell, "The past, present, and future of fracture mechanics," *Engineering Fracture Mechanics*, v. 69, p. 533-553, 2002.
[3] C.R. Myers, *et al*, "Software methodologies for multiscale descriptions of defects, deformation and fracture", *Proceedings of 10th International Conference on Fracture*, 2001.
[4] P.R. Dawson, "Computational crystal plasticity", *International Journal of Solids and Structures*, v. 37, p. 115-130, 2000.